NBSIR 76-1060

NBS InterAgency Transducer Project Progress Report No. 4

P. S. Lederer, J. S. Hilten, C. F. Vezzetti, and J. F. Mayo-Wells

Electronic Technology Division
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

June 10, 1976

Progress Report Covering Period July 1, 1975 to December 31, 1975

This is a progress report. The work is incomplete and is continuing. Results and conclusions are not necessarily those that will be included in a final report.

Prepared for

Naval Air Systems Command, U. S. Navy, and
Transducer Committee, Telemetry Group, Range Commanders Council

NBSIR 76-1060

NBS INTERAGENCY TRANSDUCER PROJECT PROGRESS REPORT NO. 4

P. S. Lederer, J. S. Hilten, C. F. Vezzetti, and J. F. Mayo-Wells

Electronic Technology Division
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

June 10, 1976

Progress Report Covering Period July 1, 1975 to December 31, 1975

This is a progress report. The work is incomplete and is continuing. Results and conclusions are not necessarily those that will be included in a final report.

Prepared for
Naval Air Systems Command, U. S. Navy, and
Transducer Committee, Telemetry Group, Range Commanders Council

U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, ***Secretary***
James A. Baker, III, ***Under Secretary***
Dr. Betsy Ancker-Johnson, ***Assistant Secretary for Science and Technology***
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Acting Director***

NBS InterAgency Transducer Project

Progress Report No. 4, for the Period
July 1, 1975 to December 31, 1975

to the

Naval Air Systems Command,
U. S. Navy, and Transducer Committee,
Telemetry Group,
Range Commanders Council

NBS Cost Center 4253434

Prepared by

Paul S. Lederer, John S. Hilten
Carol F. Vezzetti, and J. Franklin Mayo-Wells

ABSTRACT

Initial experimental efforts are described relating to the development and evaluation of means to reduce the effects produced by thermal radiant-energy transients and other thermal inputs on pressure-transducer response. Results from earlier work suggest that a major source of the thermally induced zero shifts observed in a number of pressure transducer designs is thermal energy propagated through the diaphragm to the sensing element. For many transducer designs, the temperature at the back side of the diaphragm provides a convenient measure of the energy reaching the sensing element. Accordingly, a series of tests was carried out to investigate the effects of a variety of protective coatings on the amount and rate of energy transmission through the diaphragm as revealed by measurements of the diaphragm back-side temperature. For purposes of experimental simplicity, mounted thin metal disks are used to simulate transducer diaphragms, and the temperature histories of both bare and protected disks are measured with thermocouples following exposure of the disks to thermal radiant-energy transients (of approximately 20 mJ/mm^2 at the disk) generated by No. 22 photographic flashbulbs. Protective means investigated include various materials, such as tapes, greases, and room-temperature-vulcanizing rubbers (RTVs), applied directly onto the disks as coatings. Data are given for each protective material tested.

A description of other transducer-related work and publications is given in an appendix.

Key words: Coatings; photoflash bulb; pressure transducer; protective coatings; thermal radiant-energy response; thermal transient response; transducer.

1. INTRODUCTION

A brief background for the NBS InterAgency Transducer Project, its recent history, and current objectives were given in a previous report[1]*. The task of developing a test method for evaluating the effects of short-duration, thermal radiant-energy transients on pressure-transducer response has been completed [2,3,4]. The Transducer Committee** and NAVAIR as cosponsors have assigned as a follow-on task for the Project the evaluation of schemes in use or proposed to reduce such effects. The intent is to use the test method described in [4] for evaluating protection from radiant-energy transients and to modify this method as required for generating other thermal inputs to the test transducer and protection scheme. The task assignment calls for schemes to protect pressure transducers from "radiated and/or convected transients of various amplitudes and durations." The main concept to be taken into account is the "effect of any protection scheme on transducer performance, such as increased acceleration sensitivity, degradation in dynamic performance, etc."

Goals of the work include development, for users, of guidelines and protective schemes for the use of existing pressure transducers in applications in which thermal inputs are present and, for manufacturers, recommendations relating to pressure transducer design and construction.

As noted in [3], a survey of transducer users at military test ranges and at other agencies indicated that there exists a sufficiently wide variety of applications, transducers, and measurement conditions to prevent the selection of representative instruments or measurement environments. With the concurrence of NAVAIR and the Transducer Committee, the first phase of the work (1) uses the test method of [4] with No. 22 flashbulbs as source, (2) is concerned with flush-diaphragm transducers with full-scale ranges of 0.35 and 6.9 MPa and either strain-gage or piezoelectric sensing elements, and (3) evaluates thermal protection either provided by diaphragm coatings applied in-house or based on path geometry. Further work, covering a broader range of transducers and conditions is to be proposed as indicated or justified by the results of the first-phase investigations. The plan of work is first, to develop a method for evaluating coating performance; second, to test a number of coatings using this method; third, using the test method of [4], to determine the zero shifts of pairs of transducers — one with diaphragm protection and the other without; and fourth, to compare the dynamic response of the two transducers in each pair to a shock-excited pressure wave. Work with geometric protective schemes is to follow a similar line of development.

---

*Figures in brackets indicate literature references, Section 5.
**Transducer Committee, Telemetry Group, Range Commanders Council.

2. EXPERIMENTAL DEVELOPMENT

Experimental work carried out during this reporting period was concerned with the first and second elements of the plan of work given above.

2.1 Development of Method for Evaluating Coating Performance

Parameters of interest in characterizing coating performance include the maximum rise in temperature measured at the back surface of a transducer diaphragm following a specified thermal input to the protected front surface and the time from the onset of the thermal transient to the peak back-side temperature. These parameters are of interest because results from earlier work together with knowledge of transducer design and construction suggest that a major source of the thermally induced zero shifts observed in a number of pressure-transducer designs is thermal energy propagated through the diaphragm to the sensing element. For transducer designs in which little thermal energy is conducted through the housing from diaphragm to sensing element, the temperature at the back side of the diaphragm provides a convenient measure of the energy reaching the sensing element. For purposes of evaluating coating performance, it is not necessary to accept the experimental complexity that would be involved in using an actual transducer diaphragm. A thin metal disk mounted in a relatively massive housing simulates the thermal behavior of a diaphragm; virtually identical disks may be fabricated for as many tests as are required.

2.1.1 Preliminary Work. In order to gain familiarity with making thermocouple measurements of the temperature of thin disks, preliminary work was carried out with a number of thermocouple systems, wire sizes, and mounting means. Thermocouples of the system copper versus copper-45% nickel were used initially because of their availability. Thermocouples of the system nickel-10% chromium versus copper-45% nickel offer greater sensitivity and were used as soon as they became available.

Thermocouples with wire sizes as small as 0.025 mm were tested, but were found to pose too many practical difficulties in handling; thermocouples of wire of twice this diameter proved to be acceptable. Several mounting schemes were tried including soldering and cementing. The very small size of the measuring junction of a thermocouple made with even 0.076-mm-diameter wire renders it nearly impossible to determine if the junction is in good contact with the disk when these techniques are employed. A system was devised in which the thermocouple is mounted at one end of a small ceramic rod with two axial holes for the wires. Before the thermocouple is inserted, the junction end of the rod is tapered as shown in figure 1. The thermocouple is held in place with a small quantity of white glue packed into the end of each hole. The thermocouple-and-rod assembly is mounted in a swinging bracket in such a manner that a counterweight forces the thermocouple against the disk with an adjustable force. This arrangement is shown in the sketch of figure 1.

2.1.2 Description of Apparatus. The apparatus for the test method for evaluating coating performance is based on that for evaluating the effects of thermal radiant-energy transients on pressure-transducer response. A source and the transducer mounting of the latter method are mounted on an optical rail. The mounting fixture for the thin metal disk, shown in figure 2, fits into the transducer mounting block. The vertical position of the disk, the plane of which is perpendicular to the long axis of the rail, is adjusted until the center of the disk and the center of the source are in the same horizontal plane. The mechanism for supporting the thermocouple is also mounted on the rail, behind the transducer mounting block. The arrangement is shown in figure 3. The vertical position of the thermocouple is adjusted so that the measuring junction is in contact with the approximate center of the exposed portion of the disk.

The thermocouple cold junction is immersed in a flask of water at nominal room temperature, the water being used as a heat sink to eliminate small fluctuations to which the junction would be exposed in room air. The thermocouple output is displayed on an oscilloscope triggered by the same switch used to initiate the flash. The thermocouple manufacturer provides tables for converting thermal emf in millivolts to temperature.

The source used is the No. 22 photographic flashbulb. The performance characteristics of these flashbulbs has been characterized and is given in [4]. The source-to-disk distance selected is 70 mm, which results in a transient of approximately 20 mJ/mm^2 at the disk.

2.1.3 Procedure. In the following procedure, the word "disk" refers to either a bare disk or a disk with protective material applied. Preparation of the disks is described in section 3.

(1) Select a disk mounting fixture with the aperture desired for the test. Clamp the disk between the body of the fixture and the clamping plate. Be careful to center the disk on the aperture, so that the screw holes are unobstructed. Insert the screws and tighten them evenly, in rotation.

(2) Insert the disk mounting fixture into the transducer mounting block.

(3) Mount the thermocouple assembly onto its bracket. Adjust the height of the bracket so that with the ceramic rod parallel to the rail, the distance from the measuring junction to the rail is equal to the distance from the center of the disk to the rail.

(4) Adjust the position of the counterweight so that with the ceramic rod parallel to the rail, firm pressure is felt by the tip of a finger held against the measuring junction in contact with the back surface of the disk, the ceramic rod is parallel to the rail. Be careful to prevent the measuring junction or ceramic rod from striking the interior of the disk mounting fixture.

(5) Move the thermocouple bracket assembly along the rail toward the mounted disk until, with the measuring junction in contact with the back surface of the disk, the ceramic rod is parallel to the rail. Be careful to prevent the measuring junction or ceramic rod from striking the interior of the disk mounting fixture.

(6) Immerse the thermocouple cold junction in a flask of water.

(7) Make all the electrical signal and power connections required.

(8) Adjust the oscilloscope controls as appropriate. *Note* — A total sweep time of 0.1 to 10 s is convenient. For the work described in this report, vertical deflections of 0.05 to 0.5 mV per division were adequate.

(9) Install a No. 22 flashbulb in the source position. Rotate the bulb so that the supporting electrodes for the igniter element point in a direction perpendicular to the long axis of the rail.

(10) Fire the flashbulb. *Note* — The No. 22 flashbulb constitutes a very bright source; it is recommended that the test operator not look at the bulb during ignition.

(11) If desired, record photographically the resulting trace on the oscilloscope screen.

(12) As a minimum, measure and record the following data: (1) the maximum thermocouple output and the output at 50, 100, 500, and 1000 ms after initiation of the flash and (2) the times required for the thermocouple output to reach 10, 50, 90, and 100% of the maximum value and to decay to 90 and 50%. If the sweep duration permits, measure and record thermocouple output at 5 and 10 s.

(13) Retract the thermocouple bracket assembly until the ceramic rod is clear of the transducer mounting block. Support the counterweight to prevent the rod from striking the interior of the disk mounting fixture or other parts of the apparatus.

(14) Remove the disk mounting fixture from the transducer mounting block and disassemble the fixture to remove the disk. Remove the used flashbulb in preparation for another test.

2.1.4 Experiments with Various-Sized Apertures and Disk Thicknesses. To show the effect of aperture size, i.e., of the exposed area of the disk, on the temperature history of the disk following exposure to a given thermal transient, disk mounting fixtures with three different apertures were fabricated. The apertures are chosen to be representative of commercial pressure transducers and are 6.35, 9.53, and 12.7 mm in diameter (with areas of 31.7, 71.3, and 127 mm^2, respectively).

Experiments with three disk thicknesses — 0.080, 0.13, and 0.25 mm — were also conducted. The intent of these tests was to determine if

a thin, bare disk would experience a greater temperature rise following exposure to a given thermal transient than would an otherwise similar disk of greater thickness. A simple analysis suggests that this is correct because, if the paths by which thermal energy may be removed from the disk are approximately the same in both cases, a thin disk will have to accommodate more energy per unit volume than a thicker disk.

The results of these experiments are plotted in figures 4, 5, and 6. Each of these figures shows curves of thermocouple output as a function of time for the three disk thicknesses. The tests represented by figure 4 used an aperture of 6.35 mm; those represented by figure 5, 9.53 mm; and those represented by figure 6, 12.7 mm. Comparison for the same disk thickness of the curves of these figures shows that the rates of temperature rise and decay are greatest for the smallest aperture and least for the largest, with the differences in rate of decay being the more pronounced. Again for the same disk thickness, curves from the middle-sized aperture show the highest maximum temperature rise, or, in the case of the thickest disk, a temperature rise equal to the highest. Table 1 presents maximum temperature-rise values for nine experiments, with value being an average from five tests. The curves in each figure show that disk thickness is inversely related to maximum temperature rise in a non-linear fashion and that the rates of temperature rise and decay are similar for these three thicknesses.

2.1.5 Experiments to Determine Method Repeatability. Twelve tests were conducted, each on a new bare disk, to determine the repeatability of the method. The results are given in table 2 and plotted as the heavy curve in figures 7 and 8. The thermocouple used in these tests was fabricated from 0.051-mm-diameter wires of nickel-10% chromium and copper-45% nickel and represents the "standard" thermocouple used in all tests for which numerical results are reported. The disks were fabricated from 0.080-mm-thick stainless steel. The thermocouple manufacturer indicates that the nickel-10% chromium versus copper-45% nickel thermocouples supplied satisfy the ANSI Type E specifications.

The manufacturer cites a limit of error of ±1.7°C over the range of 0 to 315°C for this type of thermocouple. This is a systematic error, however, and does not enter into the repeatability tests of concern here. During these tests, the coefficient of variation was found to be 9.4% (as shown in table 2). This is only slightly greater than the coefficient of variation of 8.7% found during repeatability tests of the #22 flashbulbs. Earlier, preliminary, tests using thermocouples soldered or glued (two sets of tests) to the back of the diaphragm resulted in data with coefficients of variation of 28%, 33%, and 17%, respectively. Hence the pivoting, mechanically held thermocouple is considered quite adequate for these investigations.

The protection provided by 16 different coatings was evaluated using the method. The coatings are identified in the column labeled

"protection" in table 3. Included are 3 two-component room-temperature-vulcanizing rubbers (RTVs), 5 single-component RTVs, 2 vinyl tapes, a "thermal" fiberglass tape, a silicone "heat-sink" compound, and a silicone dielectric grease. Five tests were made of each coating.

Each coating was applied to a stainless-steel disk 0.080 mm thick; the aperture selected for all tests is 9.53 mm in diameter. These dimensions are intended to provide the highest temperature rise as far as the disk by itself is concerned, and, consequently, the greatest sensitivity for the method. The RTVs were cast in place using a metal washer which was discarded after the material had set. The thickness of the RTV layers is 0.8 mm. The tapes, in both single and triple layers, were cut to fit the aperture by means of a cork-borer-like tool. The single-layer thickness is approximately 0.15 mm. The two silicone greases require peripheral support in a vertical position. The restraint is a washer similar to that used for casting the RTV layers and is 0.8 mm thick. The restraint is left in place as part of the coated disk. For these two coatings, clamping plates were fabricated which are thinner than the "standard" plate by the thickness of the restraining washer. The mass of the metal in front of the disk itself is thus the same for all tests.

The results of the coating-evaluation tests are given in table 3 and plotted in figures 7 and 8. Each value or data point represents the average of 5 tests. Inspection of the figures and the data shows several interesting results. As examples, one commonly used material — a single layer of black vinyl tape — increases the maximum temperature rise by a factor of 1.4, while delaying the time of the peak by a factor of 2. One of the commonly used RTVs decreases the maximum temperature rise by a factor of 5.3, while delaying the time of the peak by a factor of 6.5. In general, except for the dielectric silicone grease, all coatings tend to flatten the rate of temperature rise. The "heat-sink" compound provides a very flat "peak" with one of the longest delays and the smallest temperature rise. The information presented should be regarded as providing an indication of the nature of the protection afforded by each coating, as evaluated by the method. Further work is required to evaluate the effectiveness of each coating in reducing or eliminating transducer zero shift following exposure of the transducer to a thermal radiant-energy transient.

A selection of photographs of oscilloscope traces is given in figure 9.

4. PLANS FOR THE REPORTING PERIOD JANUARY 1 TO JULY 1, 1976

Scheduled for the reporting period January 1 to July 1, 1976 are the third and fourth elements of the plan of work given in section 1. Pairs of quartz-crystal and unbonded-strain-gage flush-diaphragm transducers will be used. Data from shock-tube tests will be captured in a transient recorder and analyzed to identify resonant frequencies. Amplitude of selected frequencies will be measured. Evaluations of the protection provided from a convective heat source will be carried out for various coatings using a modification of the method described

in this report. Experimental work will begin on geometric protection schemes.

It should be noted that funding constraints may severely limit the carrying out of some or all of these proposed tasks.

5. REFERENCES

[1] Lederer, P. S., and Hilten, J. S., NBS InterAgency Transducer Project — Progress Report Covering Period July 1, 1974 to September 30, 1974, NBSIR 75-654 (February 1975).

[2] Lederer, P. S., Hilten, J. S., and Vezzetti, C. F., NBS Inter Agency Transducer Project — Progress Report Covering Period October 1, 1974 to December 31, 1974, NBSIR 75-732 (June 1975).

[3] Lederer, P. S., and Hilten, J. S., NBS InterAgency Transducer Project — Progress Report No. 3 Covering Period January 1, 1975 to June 30, 1975, NBSIR 76-1038 (March 1976).

[4] Hilten, J. S., Vezzetti, C. F., Mayo-Wells, J. F., and Lederer, P. S., Test Method for Determining the Effect of Thermal Transients on Pressure-Transducer Response, NBS Tech. Note 905 (March 1976).

6. APPENDIX: SELECTED TRANSDUCER-RELATED INFORMATION

6.1 NBS Inter Agency Project

The report *A Test Method for Determining the Effect of Thermal Transients on Pressure-Transducer Response*, by J. S. Hilten, C. F. Vezzetti, J. F. Mayo-Wells and P. S. Lederer has been published as NBS Tech. Note 905. The abstract follows:

> A test method for evaluating the effects of short-duration, thermal radiant-energy transients on pressure-transducer response is described. The method consists of monitoring pressure-transducer output (zero shift with the transducer at atmospheric pressure) as the transducer is exposed to radiation resulting from ignition of a photographic flashbulb or from the discharge of an electronic flash. The method is intended to serve as an initial screening test. Thermal energy pulses as great as 0.1 J/cm^2, with durations of about 37 ms, have been generated using No. 22 flashbulbs. In tests with No. 22 bulbs, 25 commercial pressure transducers have shown zero shifts ranging from 0.4% to about 400% of the full-scale output.

6.2 Publications Resulting from Other-Agency Work

6.2.1 Development of a Dynamic Pressure Calibration Technique (For NASA Langley Research Center). Vezzetti, C. F., Hilten, J. S., and Lederer, P. S., "A Method for the Dynamic Calibration of Pressure Transducers Using a Liquid Medium", NBS Technical Note 914.

A method is described for producing sinusoidally varying pressures up to 34 kPa, 0-peak between 50 Hz and 2 KHz for the dynamic calibration of pressure transducers. The method uses a 10-cm column of dimethyl siloxane liquid vibrated on the armature of a vibration exciter. The high frequency capability of the method is accomplished by damping the liquid column with a section packed with steel balls. Calibration results are included for transducers provided by the sponsor.

6.2.2 Dynamic Calibration Methods for Pogo Pressure Transducers (For NASA G. C. Marshall Space Flight Center). Hilten, J. S., Lederer, P. S., Vezzetti, C. F., and Mayo-Wells, J. F., "Development of Dynamic Calibration Methods for Pogo Pressure Transducers" NBS Technical Note, to be published in 1976.

Two methods are described for the dynamic calibration of pogo pressure transducers used to measure oscillatory pressures generated in the propulsion system of the space shuttle. Rotation of a mercury-filled tube in a vertical plane at frequencies below 5 Hz generates sinusoidal pressures up to 48 KPa, peak-to-peak; vibrating the same mercury-filled tube sinusoidally in the vertical plane extends the frequency response from 5 Hz to 100 Hz at pressures up to 140 KPa, peak-to-peak. The sinusoidal pressure fluctuations can be generated by both methods in the presence of high pressures (bias) up to 55 MPa. The results from the dynamic calibration of several transducers are reported, using both methods.

6.3 Standards Activity

Four ISA Transducer Standards which had been submitted to ANSI were approved by ANSI. These documents, after revision, will be reprinted by ISA as ANSI Standards. They are:

ANSI MC6.1 "Electrical Transducer Nomenclature and Terminology" (ISA-S37.1-1969). Approved September 10, 1975.

ANSI MC6.2 "Strain Gage Pressure Transducers, Specifications and Tests For" (ISA S37.3-1970). Approved October 23, 1975.

ANSI MC6.3 "Strain Gage Linear Acceleration Transducers, Specifications and Tests For" (ISA S37.5-1969). Approved October 23, 1975.

ANSI MC6.4 "Piezoelectric Pressure and Sound-Pressure Transducers, Specifications and Tests For" (ISA S37.10-1969). Approved October 23, 1975.

6.4 Transducer-Related NBS Publications

A variety of activities at NBS related to transducers and to their calibration results in publications. In order to enhance the

dissemination of this information, the following references and abstracts are presented:

6.4.1 Piezoelectric Accelerometer Low-Frequency Response by Signal Insertion Methods. Koyanagi, R. S., and Pollard, J. D., NBSIR 74-597, May 1975.

The purpose of this study was to compare the frequency response of selected piezoelectric accelerometers, using a signal insertion method, to the response using a traditional mechanical vibration test. Signal insertion methods included "voltage insertion" and "charge insertion" techniques. The signal is inserted in series with the electrical low-side of the accelerometer by means of a suitable series resistance. Commercially available insertion devices were used. Confidence in the use of insertion methods is increased where there is agreement between the results from insertion tests and mechanically excited tests.

6.4.2 Piezoelectric Polymer Transducer for Impact Pressure Measurements. DeReggi, A. S., NBSIR 75-740, July 1975.

Described are development efforts relating to the design, construction, and calibration of a piezoelectric polymer transducer for the recording of pressure transients developed over the interface between two bodies as a result of impact. A bilaminate design was selected which uses electrically poled sheets of 25-μm poly(vinylidene fluoride) as the active material. The intended primary response of the transducer is to compression in the thickness direction, which is produced by either hydrostatic or normal pressure; the transducer was also found to respond to extension in the membrane direction. Individual-sheet activity in the thickness-compression mode is approximately 15 pC/N, resulting in a bilaminate transducer pressure response of 4.5 μV/Pa (30 mV/psi). Instructions for poling sheets and for constructing transducers are given in detail. Static and dynamic methods for characterizing transducer output are described. In particular, in order to simulate field conditions in which the transducer may bend or stretch, or both, during impacts, a drop-test procedure with curved impactors has been devised, and a theoretical analysis (simplified to the extent of considering the membrane-stress contribution negligible) has been developed to yield the interface pressure.

6.4.3 A Guide to Methods and Standards for the Measurement of Water Flow. Kulin, G., and Compton, P. R., NBS Special Publication 421, May 1975.

Selected information sources on methods and standards for making measurements of water and wastewater flow in the

field are listed and described. Both closed conduit and free surface flows are treated, but emphasis is on open channel flow measurements needed in water resource engineering and in water pollution control. Instruments and methods covered include weirs, flumes, current meters (and velocity traverse methods), dilution techniques, pipe flow instruments, acoustic meters and others. In addition to summarizing the basic properties of each instrument or method and referring users to the best available sources of detailed information on performance and field application, potential sources of error are described and quantified where possible.

TABLE 1

Maximum Temperature-Rise Values for Combinations of Three Disk Thicknesses and Three Apertures*

Disk Thickness (mm)	Aperture Diameter (mm)	Maximum Temperature Rise** (Celsius degrees)
0.080	6.35	20.0
0.080	9.53	21.3
0.080	12.7	19.2
0.13	6.35	13.7
0.13	9.53	16.5
0.13	12.7	15.6
0.25	6.35	17.2
0.25	9.53	8.07
0.25	12.7	8.34

*The disks were fabricated from stainless steel and were positioned 70 mm from the No. 22 flashbulb source, as described in the text. The thermocouple is of the system nickel-10% chromium versus copper-45% nickel.

**Each value represents the average from five tests.

TABLE 2

Repeatability Tests

Run No.	Maximum Thermocouple Output (mV)	Time of Maximum Output (ms)
1	1.12	500
2	1.12	510
3	1.26	380
4	0.96	450
5	1.16	300
6	1.18	300
7	1.16	320
8	1.16	270
9	1.06	320
10	0.94	340
11	0.94	350
12	1.08	280

Maximum Thermocouple Output	Time of Maximum Output
sample mean = 1.095 mV	sample mean = 360 ms
sample standard deviation = 0.103 mV	sample standard deviation = 83.1 ms
coefficient of variation = 9.4%	coefficient of variation = 23%

TABLE 3

Results of Tests on Coatings

Coating	Thermocouple Output* Maximum (mV)	Corresponding Temperature Rise** to Maximum (Celsius degrees)	Coefficient of Variation (%)	At 50 ms (mV)	At 100 ms (mV)	At 500 ms (mV)	At 1 s (mV)	At 5 s (mV)	At 10 s (mV)	Times: Rise Times to Given Percent of Maximum Temperature Rise: To 10% (ms)	To 50% (ms)	To 90% (ms)	To 100% (ms)	Down-Curve Times to Given Percent of Maximum Temperature Rise: To 90% (ms)	To 50% (ms)	Coating Code
No Coating (Q)	1.10	18	9.4	0.32	0.75	1.06	0.08	—	—	33	70	660	360	673	—	(Q)
Two-Component Red RTV (A)	0.20	3.4	11	0.00	0.00	0.05	0.13	0.17	0.10	340	760	1370	2340	4400	9600	(A)
Two-Component Red RTV (B)	0.26	4.4	12	0.01	0.01	0.14	0.24	0.18	0.10	200	470	950	1560	3120	7700	(B)
Single-Component Black RTV (C)	0.57	9.6	15	0.00	0.00	0.10	0.35	0.46	0.25	390	850	1520	2500	4060	8740	(C)
Single-Component Aluminum RTV (D)	0.45	7.6	14	0.14	0.32	0.43	0.44	0.31	0.16	320	70	260	1140	2700	5900	(D)
Single-Component White RTV (E)	0.53	9.0	21	0.23	0.46	0.44	0.35	—	—	28	56	110	180	370	—	(E)
Single-Component White RTV (F)	0.53	9.0	17	0.29	0.49	0.40	0.32	—	—	25	46	90	150	300	—	(F)
Single-Component White RTV (G)	0.54	9.1	24	0.26	0.48	0.42	0.32	—	—	26	53	100	170	300	—	(G)
Two-Component White RTV (H)	0.17	2.9	22	0.08	0.15	0.16	0.15	—	—	30	57	110	200	800	—	(H)
One Layer of White Vinyl Tape (I)	0.67	11	8.6	0.23	0.51	0.66	0.62	—	—	31	61	140	320	—	—	(I)
One Layer of Fiberglass Tape (J)	0.65	11	11	0.23	0.48	0.63	0.61	—	—	33	65	170	470	—	—	(J)
One Layer of Black Vinyl Tape (K)	1.54	25	16	0.00	0.18	1.46	1.47	0.42	0.11	90	190	380	750	1300	3200	(K)
Three Layers of White Vinyl Tape (L)	0.28	4.7	7.3	0.11	0.23	0.28	0.28	—	—	30	58	120	460	—	—	(L)
Three Layers of Fiberglass Tape (M)	0.26	4.4	12	0.08	0.20	0.22	0.25	0.20	0.11	40	70	720	1480	3300	8200	(M)
Three Layers of Black Vinyl Tape (N)	0.72	12	10	0.00	0.00	0.24	0.56	0.46	0.22	320	600	1100	1700	3300	7300	(N)
"Heat Sink" Silicone Compound (O)	0.11	1.9	23	0.01	0.04	0.09	0.11	0.06	0.04	44	160	550	960	2100	6500	(O)
Silicone Grease (P)	0.92	15	20	0.43	0.83	0.66	0.50	—	—	27	52	110	160	280	—	(P)

*Data given are averages of 5 measurements for (A) through (P) and of 12 measurements for (Q)
**From tables supplied by thermocouple manufacturer.

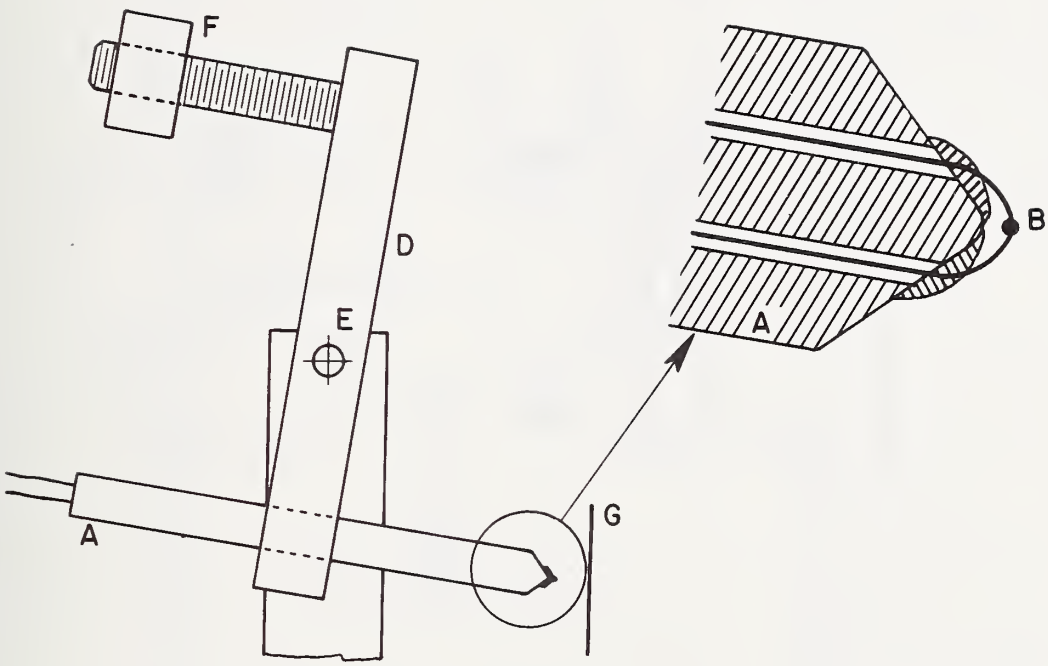

FIGURE 1: SKETCH OF THERMOCOUPLE FIXTURE WITH CROSS-SECTION DETAIL OF THERMOCOUPLE MOUNTED IN CERAMIC ROD (A). THE THERMOCOUPLE MEASURING JUNCTION IS IDENTIFIED BY (B). THE THERMOCOUPLE WIRES PROJECT BACK THROUGH TWO AXIAL BORES IN THE ROD. WHITE GLUE (C) HOLDS THE THERMOCOUPLE IN PLACE. THE THERMOCOUPLE-AND-ROD ASSEMBLY IS CLAMPED IN ARM (D) PIVOTALLY MOUNTED AT (E). THE POSITION OF THE COUNTER WEIGHT (F) MAY BE ADJUSTED TO CONTROL THE FORCE EXERTED BY THE JUNCTION AGAINST THE DISK (G).

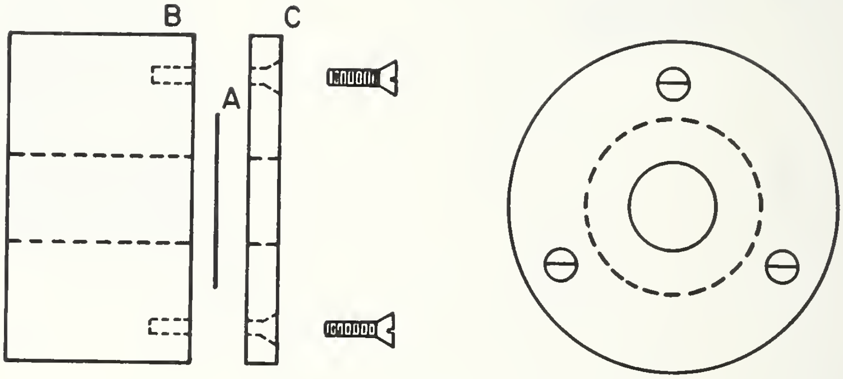

Figure 2: Sketch of disk mounting fixture. The side view at the left shows the fixture disassembled with the disk (A) in position ready to be clamped to the body (B) by clamping plate (C). As explained in the text, the diameter of the bore determines the aperture, that is the area of disk exposed to thermal radiant energy. The outer diameter of the fixture is set by the requirements of the transducer mounting block.

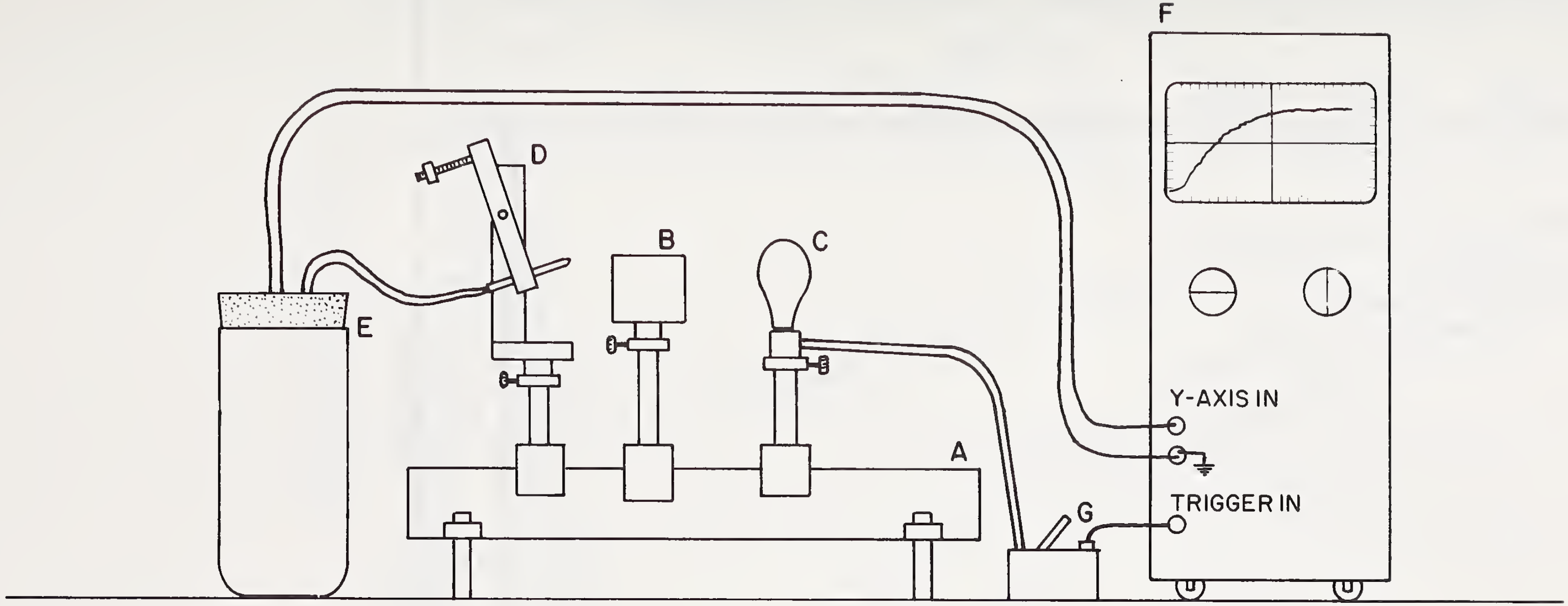

FIGURE 3: ARRANGEMENT OF THE TEST-METHOD APPARATUS. MOUNTED ON OPTICAL RAIL (A), ARE THE TRANSDUCER MOUNTING BLOCK (B), THE THERMAL RADIANT-ENERGY SOURCE (C), AND THE THERMOCOUPLE BRACKET ASSEMBLY (D). THE THERMOCOUPLE COLD JUNCTION IS IMMERSED IN WATER CONTAINED IN FLASK (E), AND THE THERMOCOUPLE OUTPUT SIGNAL IS DISPLAYED ON STORAGE OSCILLOSCOPE (F). THE IGNITION SYSTEM (G) FOR THE SOURCE ALSO SUPPLIES A TRIGGER SIGNAL TO THE OSCILLOSCOPE. THE DISK AND ITS FIXTURE ARE HIDDEN WITHIN THE TRANSDUCER MOUNTING BLOCK, AS DESCRIBED IN THE TEXT.

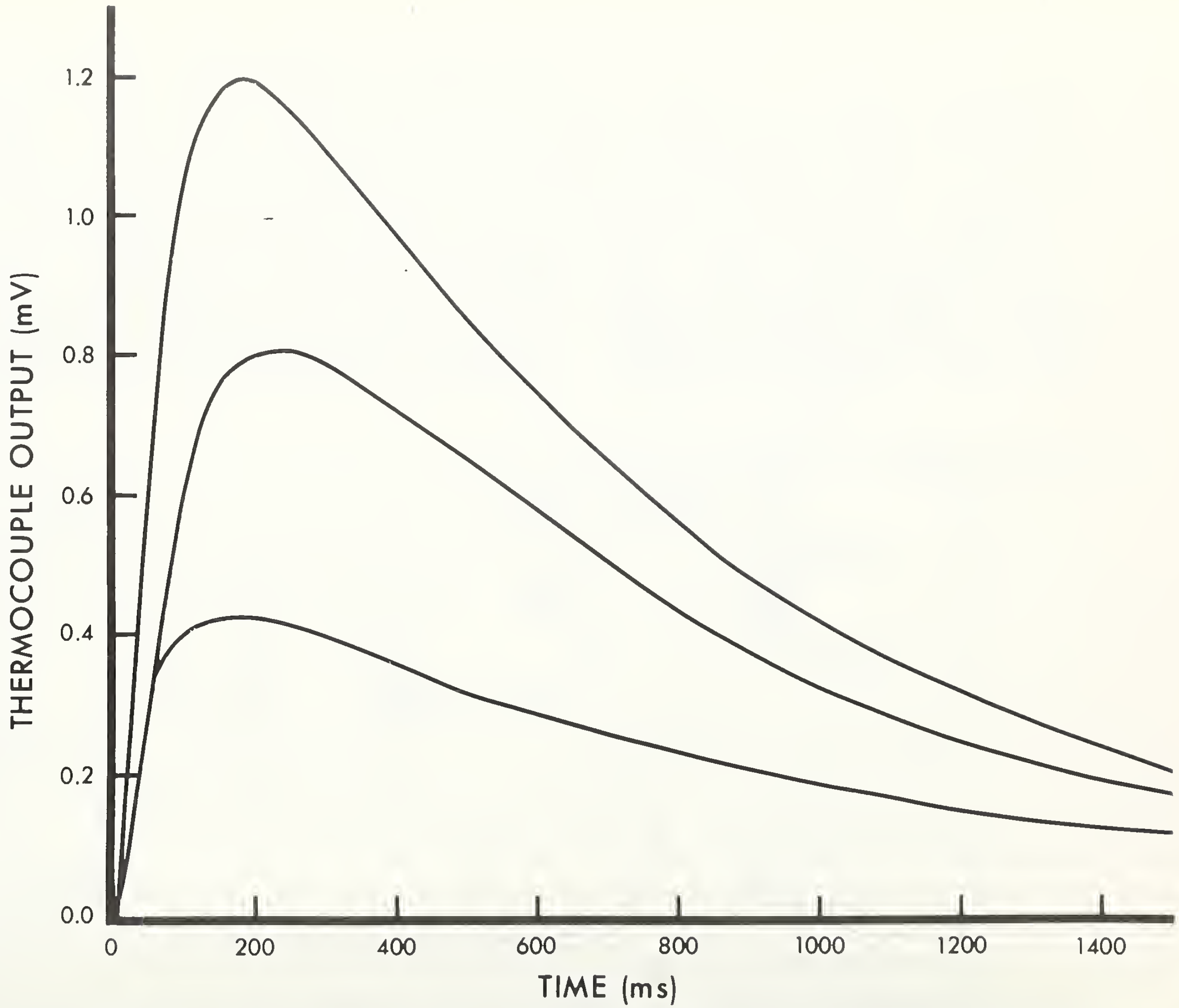

Figure 4: Thermocouple output (mV) as a function of time (ms) for three disk thicknesses, as measured by the method. As described in the text, the aperture used is 6.35 mm in diameter. The top curve represents a disk thickness of 0.080 mm; the middle curve, 0.13 mm; and the bottom curve, 0.25 mm.

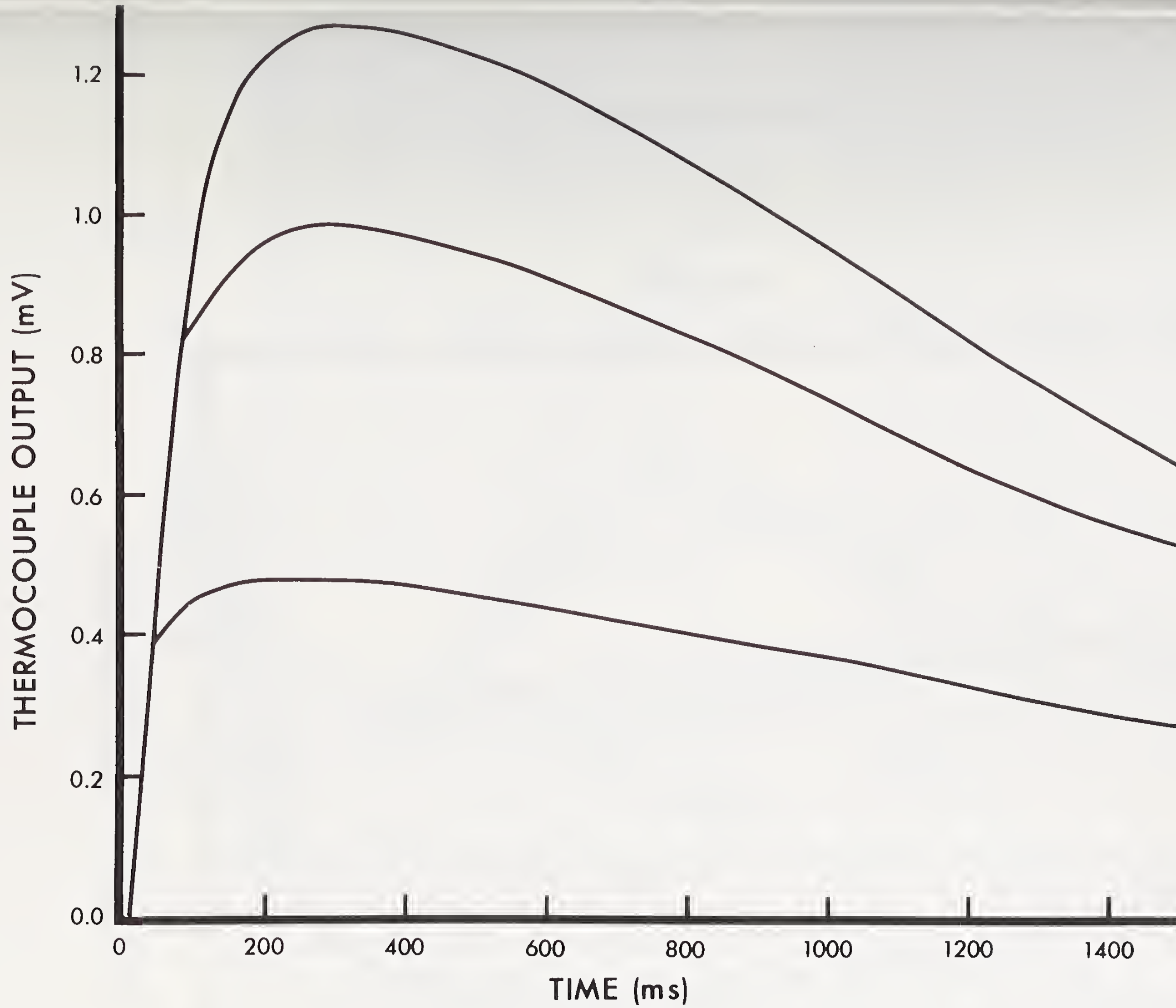

Figure 5: Thermocouple output (mV) as a function of time (ms) for three disk thicknesses, as measured by the method. As described in the text, the aperture used is 9.53 mm in diameter. The top curve represents a disk thickness of 0.08 mm; the middle curve, 0.13 mm; and the bottom curve, 0.25 mm.

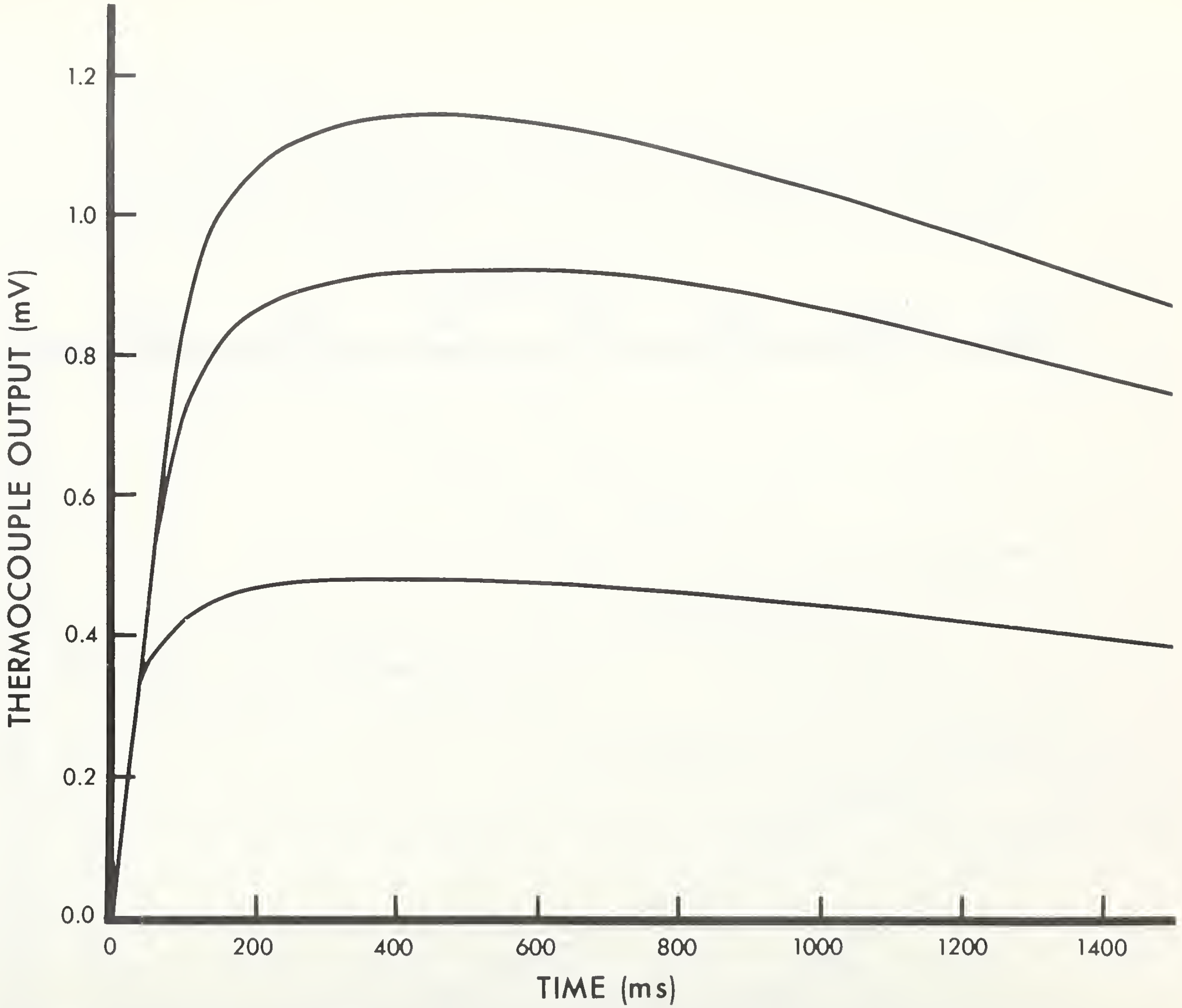

Figure 6: Thermocouple output (mV) as a function of time (ms) for three disk thicknesses, as measured by the method. As described in the text, the aperture used is 12.7 mm in diameter. The top curve represents a disk thickness of 0.080 mm; the middle curve, 0.13 mm; and the bottom curve, 0.25 mm.

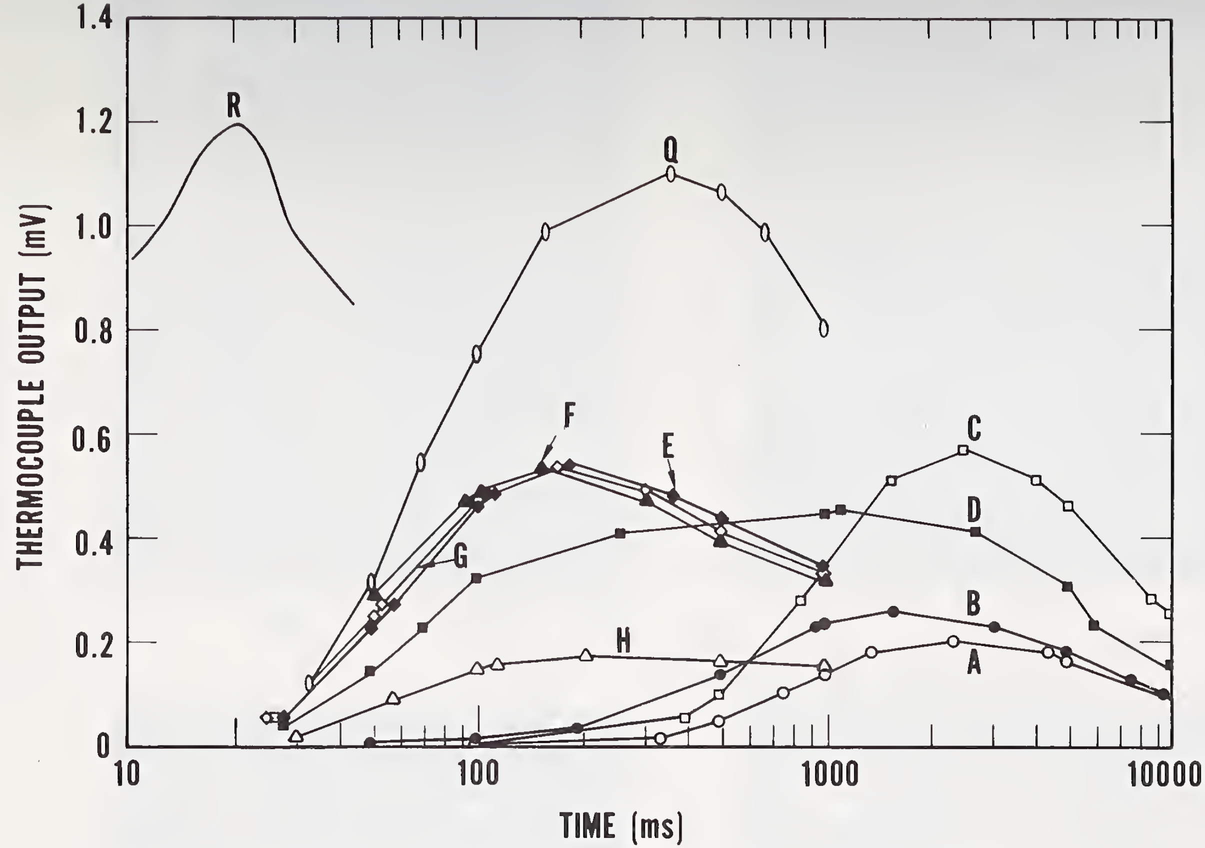

FIGURE 7: RESULTS OF TESTS USING THE METHOD ON COATINGS A THROUGH H. THE PLOTS SHOW THERMOCOUPLE OUTPUT (mV) AS A FUNCTION OF TIME (ms), WITH TIME PLOTTED ON A THREE-CYCLE LOGARITHMIC SCALE. AS A ROUGH GUIDE, 1 mV CORRESPONDS TO A RISE OF 16.6 CELSIUS DEGREES. THE PEAK OF THE SOURCE OUTPUT OCCURS AT APPROXIMATELY 20 ms, AS INDICATED BY CURVE R. AMPLITUDE FOR CURVE R IS IN ARBITRARY UNITS. THE CURVE Q REPRESENTS AN UNPROTECTED DISK FOR COMPARISON. AS DESCRIBED IN THE TEXT, EACH DATA POINT FOR THE COATING CURVES IS AN AVERAGE FROM FIVE TESTS. CURVE Q IS THE AVERAGE OF TWELVE TESTS.

COATING IDENTIFICATION:

A = TWO-COMPONENT RED RTV	E = SINGLE-COMPONENT WHITE RTV
B = TWO-COMPONENT RED RTV	F = SINGLE-COMPONENT WHITE RTV
C = SINGLE-COMPONENT BLACK RTV	G = SINGLE-COMPONENT WHITE RTV
D = SINGLE-COMPONENT ALUMINUM RTV	H = TWO-COMPONENT WHITE RTV

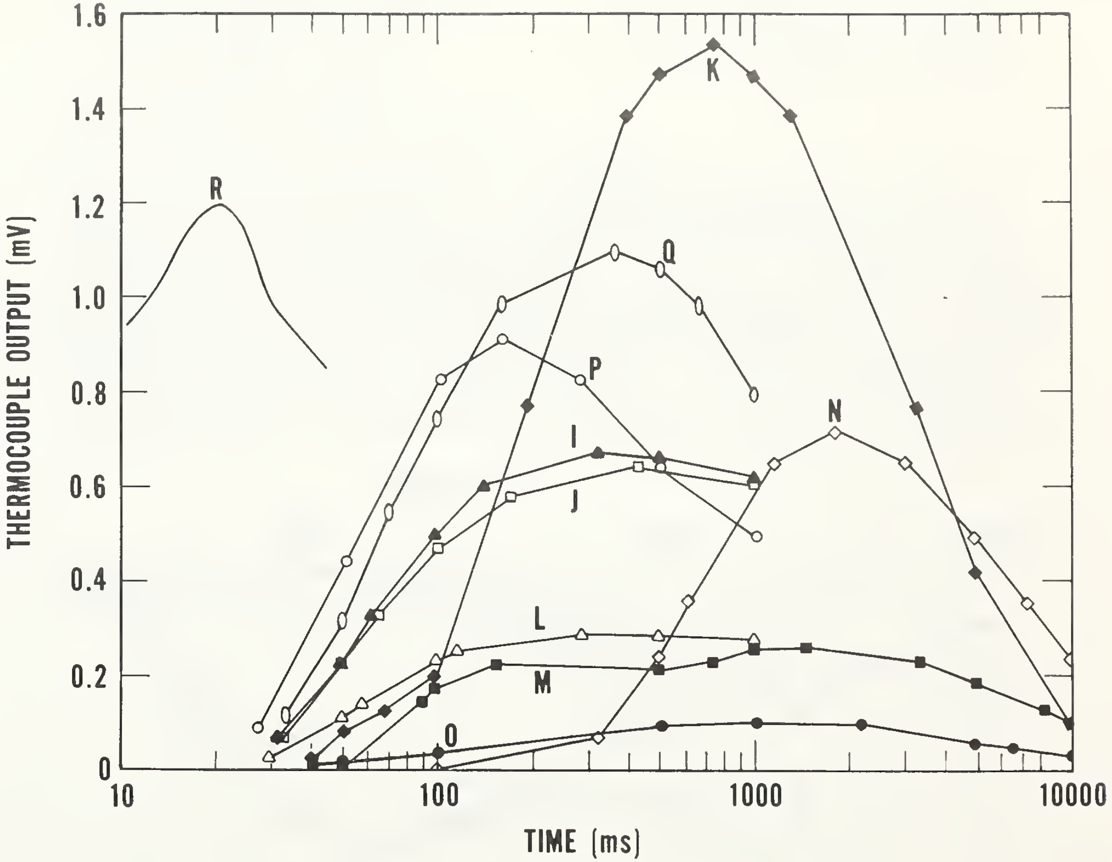

FIGURE 8: RESULTS OF TESTS USING THE METHOD ON COATINGS I THROUGH P. THE PLOTS SHOW THERMOCOUPLE OUTPUT (mV) AS A FUNCTION OF TIME (MS), WITH TIME PLOTTED ON A THREE-CYCLE LOGARITHMIC SCALE. AS A ROUGH GUIDE, 1 mV CORRESPONDS TO A RISE OF 16.6 CELSIUS DEGREES. THE PEAK OF THE SOURCE OUTPUT OCCURS AT APPROXIMATELY 20 MS, AS INDICATED BY CURVE R. AMPLITUDE FOR CURVE R IS IN ARBITRARY UNITS. THE CURVE Q REPRESENTS AN UNPROTECTED DISK FOR COMPARISON. AS DESCRIBED IN THE TEXT, EACH DATA POINT FOR THE COATING CURVES IS AN AVERAGE FROM FIVE TESTS. CURVE Q IS THE AVERAGE OF TWELVE TESTS.

COATING IDENTIFICATION:

I = ONE LAYER WHITE VINYL TAPE
J = ONE LAYER FIBERGLASS TAPE
K = ONE LAYER BLACK VINYL TAPE
L = THREE LAYERS WHITE VINYL TAPE
M = THREE LAYERS FIBERGLASS TAPE
N = THREE LAYERS BLACK VINYL TAPE
O = "HEAT-SINK" SILICON COMPOUND
P = SILICONE GREASE

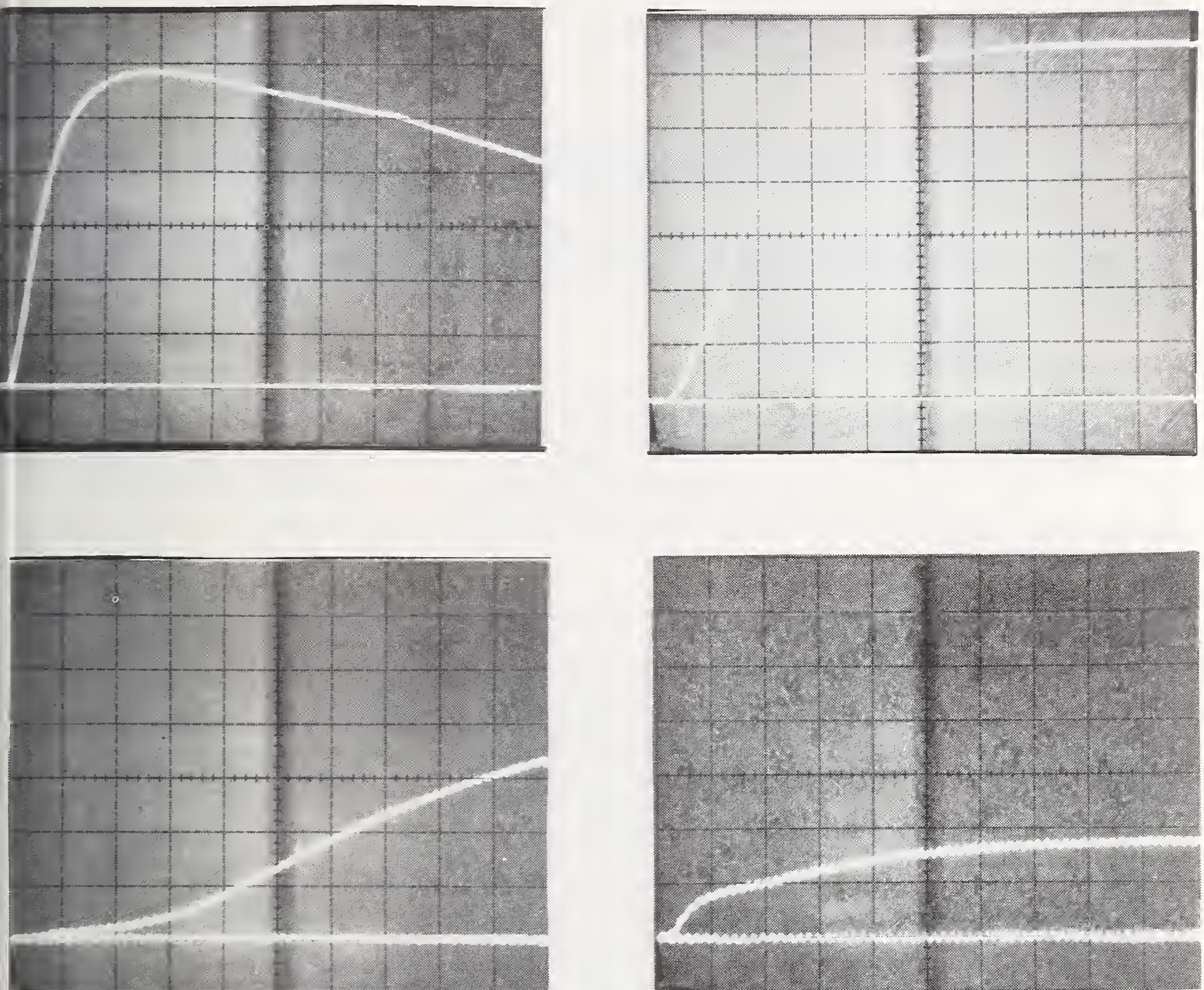

FIGURE 9: PHOTOGRAPHS OF OSCILLOSCOPE TRACES OF THERMOCOUPLE OUTPUT AS A FUNCTION OF TIME FOR FOUR TESTS USING THE METHOD. THE TOTAL SWEEP TIME IN EACH PHOTOGRAPH IS 1 s. THE UPPER LEFT PHOTOGRAPH IS FOR AN UNPROTECTED DISK (CODE LETTER Q); AND THE UPPER RIGHT, FOR ONE LAYER OF BLACK VINYL TAPE (K). THE VERTICAL SCALE FOR BOTH PHOTOGRAPHS IS 0.2 mV/DIVISION. THE BOTTOM LEFT PHOTOGRAPH IS FOR A TWO-COMPONENT RED RTV (A); AND THE BOTTOM RIGHT, FOR "HEAT-SINK" SILICON COMPOUND (O). THE VERTICAL SCALE FOR BOTH PHOTOGRAPHS IS 0.05 mV/DIVISION.

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET**	1. PUBLICATION OR REPORT NO. NBSIR 76-1060	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

NBS InterAgency Transducer Project
Progress Report No. 4

5. Publication Date April 10, 1976

6. Performing Organization Code

7. AUTHOR(S) Paul S. Lederer, John S. Hilten, Carol F. Vezzetti, and John F. Mayo-Wells

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No. 4253434

11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)*

Naval Air Systems Command
Washington, DC 20361

Transducer Committee TG/RCC
c/o Div. 9486
Sandia Laboratories
Albuquerque, NM 87115

13. Type of Report & Period Covered Interim 7/1/75 to 12/31/75

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Initial experimental efforts are described relating to the development and evaluation of means to reduce the effects produced by thermal radiant-energy transients and other thermal inputs on pressure-transducer response. Results from earlier work suggest that a major source of the thermally induced zero shifts observed in a number of pressure transducer designs is thermal energy propagated through the diaphragm to the sensing element. For many transducer designs, the temperature at the back side of the diaphragm provides a convenient measure of the energy reaching the sensing element. Accordingly, a series of tests was carried out to investigate the effects of a variety of protective coatings on the amount and rate of energy transmission through the diaphragm as revealed by measurements of the diaphragm back-side temperature. For purposes of experimental simplicity, mounted thin metal disks are used to simulate transducer diaphragms, and the temperature histories of both bare and protected disks are measured with thermocouples following exposure of the disks to thermal radiant-energy transients (of approximately 20 mJ/mm^2 at the disk) generated by No. 22 photographic flashbulbs. Protective means investigated include various materials, such as tapes, greases, and room-temperature-vulcanizing rubbers (RTVs), applied directly onto the disks as coatings. Data are given for each protective material tested.

A description of other transducer-related work and publications is given in an appendix.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Coatings; photoflash bulb; pressure transducer; protective coatings; thermal radiant-energy response; thermal transient response; transducer.

18. AVAILABILITY [X] Unlimited

[ ] For Official Distribution. Do Not Release to NTIS

[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13

[X] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151

19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
UNCLASSIFIED	25
20. SECURITY CLASS (THIS PAGE)	**22. Price**
UNCLASSIFIED	$3.50

USCOMM-DC 29042-P74